Keyboard Retraining: Qwerty to Dvorak

by

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Dvorak keyboarded by Janet Phillips for Bradley John Lessley

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Ignorance and custom are the great hindrances to progress. Every possible saving in time, materials and fatigue that enables us to get more out of life should be adopted.

Frank B. Gilbreth
Lillian M. Gilbreth
(1917)

Keyboard Retraining: Qwerty to Dvorak

I. INTRODUCTION

Today, there are 8 million people who are dependent upon an alphanumeric keyboard to perform daily employment activities. Another 10 million people use an alphanumeric keyboard in some phase of their work activity (Winger, 1977).

In 1974, 15 million people were employed in clerical and kindred occupations, and most of them required a keyboarding skill to perform at least part of their work assignment. This figure is expected to climb to 20 million by 1985 (U.S. Department of Labor, 1976). The secretarial and clerical occupations area had 4.3 million workers in 1974, with a projected increase to 6.3 million workers by 1985. Between 1974 and 1985, 16.3 million new positions in clerical and kindred occupations are expected to open due to growth and replacement of workers leaving employment (U.S. Department of Labor, 1976).

In 1873 the Remington Arms Company introduced the first marketable typewriter, invented by Christopher Latham Sholes. The keyboard arrangement came about because the action of the first typewriter models was sluggish. To avoid the clashing of typebars struck in sequence, Sholes located the most frequently used letters in different

quadrants (Herkimer County Historical Society, 1923). This keyboard arrangement, called the Qwerty keyboard, was very similar to the one used on keyboarding equipment today, as shown in Figure 1.

Prior to the turn of the century, typewriting was undertaken using the two-finger (hunt and peck) approach. Shortly after the turn of the century, touch typewriting became popular. This innovation, along with substantial improvements in the typewriter, brought about a steady increase in typewriting course enrollments. Educators, however, found it difficult to teach typewriting effectively and have students attain an optimal skill level. This difficulty was primarily due to the Qwerty keyboard, which resulted from the mechanical deficiencies of the original typewriter models (Dvorak, 1943).

Recognizing that something was fundamentally wrong with typewriting instruction, the Carnegie Corporation of New York issued two grants through the Carnegie Foundation for the Advancement of Teaching in 1932 to make possible a study of the problems of teaching and learning typewriting. The study was undertaken at the University of Washington under the direction of August Dvorak.

Inspired by the work of Frank B. Gilbreth, Dvorak used the time-and-motion study approach in the analysis of typewriting skill. His studies confirmed that the Qwerty

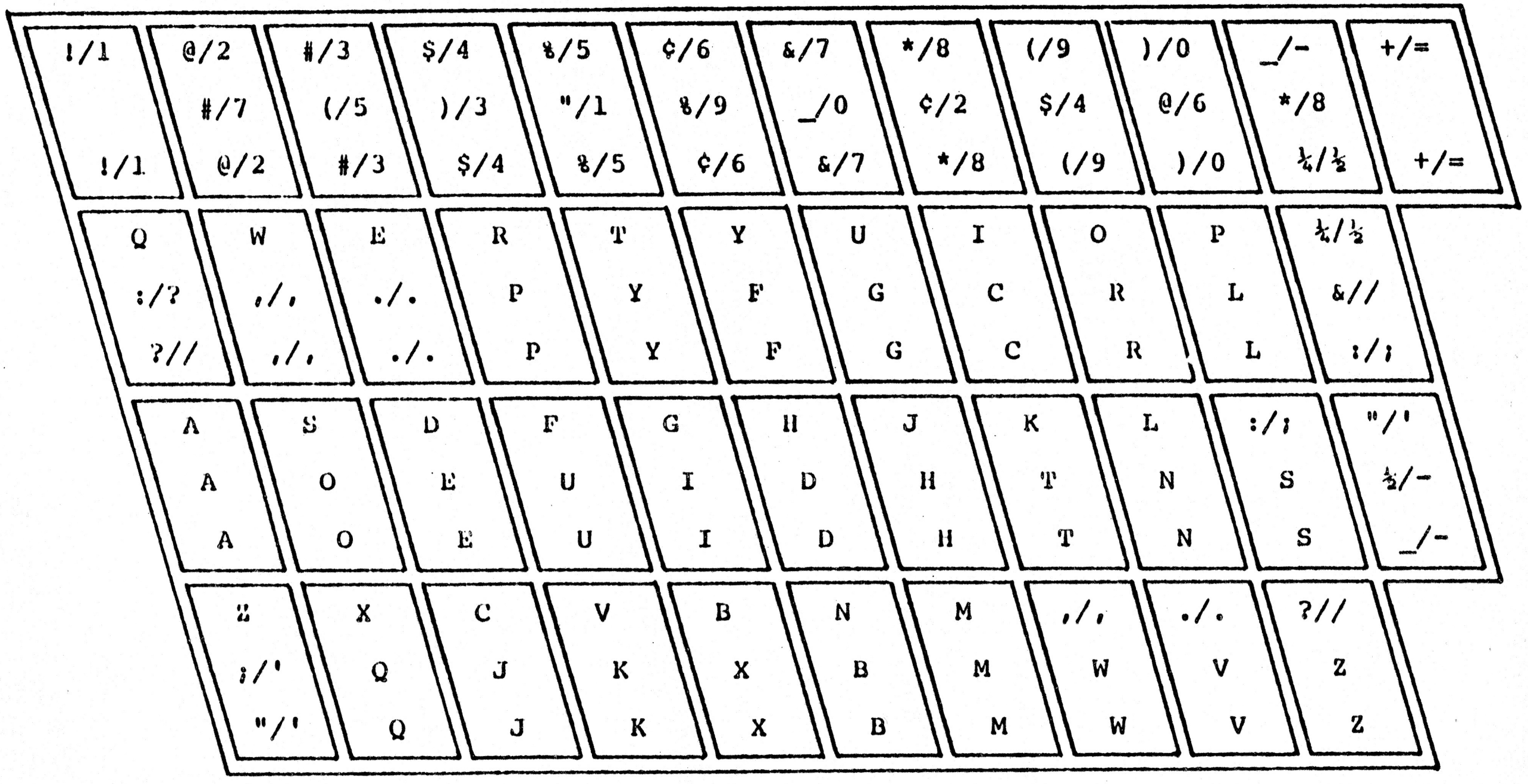

Figure 1. Arrangement of characters on Qwerty Keyboard (top figure in each block), Dvorak Simplified Keyboard (middle figure), and Dvorak Keyboard (bottom figure)

keyboard was a poor design for English language typewriting. From these studies he concluded that the following problems were inherent in the Qwerty keyboard design (Dvorak, 1943):

1. The mastery of skillful typewriting is unnecessarily difficult and time-consuming.
2. Typewriting rates are lowered by the extreme complexity of the motions.
3. Typists make more typographical errors than they would if the motions were simpler and more evenly balanced between the two hands.
4. The unnecessarily intricate and excessive motions cause mental tension, typist fatigue, and decreased efficiency and accuracy.

An alternate keyboard was designed through experimentation using scientific data relating to the frequency of use of letters and the frequency of different two-, three-, four-, and five-letter sequences. This keyboard has since become known as the Dvorak Simplified keyboard, as shown in Figure 1. With the development of this keyboard, the problems of typewriting instruction associated with the Qwerty keyboard have been minimized as follows (Dvorak, 1943):

1. Keyboarding skill can be mastered in approximately half the time required to master the Qwerty keyboard.
2. Performance rates can be increased by utilization of the Dvorak keyboard.

3. Accuracy in keyboarding can be increased by utilization of the Dvorak keyboard.
4. Fatigue can be decreased by utilization of the Dvorak keyboard.

Although the Dvorak keyboard has apparent advantages over the Qwerty keyboard, the Dvorak arrangement has not been accepted in recent years for two basic reasons:

1. Formal research studies have not been undertaken addressing performance levels and ease of operation on the Dvorak keyboard using modern office keyboarding equipment.
2. Employers are concerned about the ease and cost of converting office keyboarding equipment from the Qwerty keyboard to the Dvorak keyboard.

The advent of electronic keyboard equipment and interchangeable element typewriters has made conversion to the Dvorak keyboard easy and inexpensive. A need still remains for studies addressing performance levels and ease of operation using modern office keyboarding equipment.

Statement of the Problem

Further studies should be conducted to determine keyboard operator performance levels and ease of operation on the Dvorak keyboard using modern electronic and mechanical keyboarding equipment. The findings of these studies would

provide information regarding the potential advantages of hiring Dvorak keyboard operators.

Support for altering the keyboard arrangement came from Rencz (1978), who indicated that keyboarding was one of the most unattractive tasks performed in the office environment. He recommended that business and government should adopt a scientifically designed keyboard which would make keyboarding more attractive. He indicated, however, that research studies showing increased performance and ease of operation would have to be undertaken before the adoption of an alternate keyboard would be considered.

Winger (1977), addressing the awkward nature of the Qwerty keyboard, emphasized that the main problem to be overcome is that of gaining acceptance of a scientifically designed keyboard. He indicated that for any change to be made in the keyboard arrangement, research projects would have to be undertaken demonstrating the benefits to be derived from an alternate keyboard arrangement. Russon and Wanous (1973) and West (1969) also suggested this premise. They stated that the Qwerty keyboard is behind the times and improvement in the keyboard arrangement should be considered.

Davis (1977) indicated that American National Standards Committee X4DSK is interested in the findings of research projects addressing the use of alternate keyboard arrangements. The Committee is particularly interested in studies

addressing variants of the Dvorak Simplified Keyboard such as the Dvorak Keyboard shown in Figure 1 which is presently being considered as an alternate national standard to the Qwerty keyboard.

Educators, keyboard equipment manufacturers, and textbook publishers are very much aware of the benefits inherent in the Dvorak keyboard for both employers and keyboard operators. Before large-scale implementation of the Dvorak keyboard can come about, however, a demand for the keyboard within the public and private employment sectors must be created. Employers, educators, manufacturers, and publishers will encourage acceptance of the Dvorak keyboard only when valid research indicates that training (beginning keyboard learning and retraining) on the Dvorak keyboard leads to increased operator performance levels and ease of operation. Employers would then demand equipment and operators for this keyboard arrangement, with educators providing the keyboard operators and manufacturers supplying the keyboarding equipment.

The major purpose of this study was to provide information pertaining to performance levels of Dvorak keyboard operators through retraining. More specifically, the purposes of this study were:

1. To compare operator performance rates on the Dvorak keyboard with operator performance rates on the Qwerty keyboard.

2. To determine whether keyboard operators can learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard.

Definition of Terms

Cathode Ray Tube (CRT) Word Processor. An office text processor (electronic) which allows an operator to keyboard text onto a television-like screen where the image of the text is displayed. Printing of the original document is performed after the text has been created, edited, and verified on the screen. Vydec CRT word processors, equipped with a Dvorak/Qwerty keyboard developed by Vydec, Inc., were used in this study.

Dvorak Keyboard. An alphanumeric keyboard (variant of the Dvorak Simplified Keyboard) presently being considered by American National Standards Committee X4DSK as an alternate national standard to the Qwerty keyboard (Figure 1). The placement of all letters, the period, and the comma in this keyboard arrangement is the same as found in the Dvorak Simplified Keyboard. Other keyboard characters, however, have been repositioned to meet present correspondence keyboarding requirements.

Dvorak Simplified Keyboard. An alphanumeric keyboard patented by August Dvorak in 1936. While not used commercially, this keyboard is well known for its ease of

learning, speed and accuracy qualities, and ease of keyboard operation (Figure 1).

Element Correcting Typewriter. An electric typewriter (mechanical) with a small, spherical "golf ball" attached to a carrier (no typewriter carriage) which prints characters as it moves across the document being created. The operator corrects errors by backspacing and striking over, using a correction tape mechanism which is part of the typewriter.

Gross Words Per Minute (GWPM). The number of standard 5-stroke words divided by the number of minutes in a timed writing.

Production Skill. Completion of all activities required in the preparation of office correspondence, including keystroking, adjusting equipment, handling materials, planning work activity, proofreading, and correcting errors.

Qwerty Keyboard. An alphanumeric keyboard designed by Christopher Latham Sholes in 1873 and adopted as a national standard in 1966 by the American National Standards Institute. This keyboard, with some modification over the years, is still used on keyboarding equipment today (Figure 1). The term Qwerty was derived from the letters found in the upper left-hand portion of this keyboard.

Retraining. A method of instruction which facilitates keyboard operator conversion from the Qwerty keyboard to the Dvorak keyboard.

Straight-Copy Skill. Word-for-word keyboarding from printed material with no consideration of form or arrangement other than a right-hand margin.

Syllabic Intensity. The average number of syllables per word in timed-writing copy. The average difficulty of printed copy is 1.43.

Limitations

This study was limited by the following factors:

1. The study participants may have had a predetermined positive or negative attitude toward change.
2. The office supervisory personnel may have given varying degrees of motivational support for Dvorak keyboard retraining.
3. The demographic background (e.g. age, education, years of work experience) of the retrainees may have differed.
4. The Qwerty keyboard performance and skill levels of the study participants varied greatly.

Delimitations

This study was delimited by the following factors:

1. No attempt was made to select study participants from states other than Oregon.
2. No attempt was made to control environmental differences between offices.
3. No attempt was made to select the study participants randomly.
4. Participant performance was not measured beyond 100 hours of skill-development keyboarding.
5. The researcher relied on office supervisory personnel to coordinate on-site retraining.
6. Only two types of office keyboarding equipment were used in the study.

II. REVIEW OF RELATED LITERATURE

The review of related literature presented in this chapter addresses research studies which involved retraining keyboard operators on the Dvorak keyboard.

The Library Information Retrieval Service, William Jasper Kerr Library, Oregon State University, was employed to assist the researcher in identifying and locating available literature pertaining to the research study.

Retraining Studies

The review of retraining studies was conducted in three parts. Part I includes the years 1933-1945. During the ten-year period from 1945-1955, there was no known research on the Dvorak keyboard. Part II presents the research from 1955-1957. This was the last reported research on Dvorak keyboard retraining using manual typewriters. Part III presents the research from 1970 to the present, involving the use of electric typewriters for Dvorak keyboard retraining.

Part I--Dvorak Keyboard Research, 1933-1945

The first research study involving retraining on the Dvorak keyboard was reported by Goehring and Miller (1933). This initial experiment included five University of Washington students who volunteered for retraining during

the 1932 summer session. Each participant was given two 10-minute straight-copy timed writings prior to beginning retraining to establish a Qwerty keyboard typing rate. The average Qwerty keyboard performance rate for the five retrainees is presented in Table 1. Individual Qwerty rates were not documented for the group; however, an average rate of 56 gross words per minute (GWPM) was established.

TABLE 1. KEYBOARDING RATES (GWPM) FOR GOEHRING AND MILLER (1933) STUDY

Retrainee Number	Qwerty[a] GWPM	Dvorak[b] GWPM	% Increase GWPM
1	-- [c]	44	
2	--	60	
3	--	50	
4	--	67	
5	--	73	
Average	56	59	5.4

[a]10-minute straight-copy timed writing
[b]5-minute straight-copy timed writing
[c]Not given in the research study

Classroom instruction was held at the University of Washington over a nine-week period, five days a week, 50 minutes a day, with an average attendance of 39.8 days. Retrainees 1 and 3 did not complete the nine weeks of

instruction. Each retrainee accumulated additional Dvorak keyboard practice time outside of class; however, no records were kept for this activity. Five-minute straight-copy timed writings were given weekly to determine progress on the Dvorak keyboard.

The following findings and conclusions were presented in the study:

1. All five retrainees had ending Dvorak keyboard performance rates which were greater than their preretraining Qwerty keyboard rates.
2. A 5.4 percent increase in performance was found for the five retrainees (Table 1).
3. Dvorak keyboarding rates can surpass Qwerty keyboarding rates within a relatively short period of time.
4. Retraining was faster than original learning because of ease of learning on the Dvorak keyboard and transfer of learning.
5. All five retrainees claimed that the Dvorak keyboard was less fatiguing than the Qwerty keyboard.
6. A larger group of retrainees would be required to draw general conclusions regarding performance increase on the Dvorak keyboard.

Merrick (1940) reviewed a series of studies involving retraining of office keyboard operators on the Dvorak keyboard. The first study cited was a retraining project conducted at the Minnesota School of Business in Minneapolis. It included five operators employed by Investors Syndicate, Pillsbury Flour Mills Company, and Educational Publishers. The project director was August Dvorak. The second study was sponsored by and held in the offices of the United Pacific Insurance Company in Seattle, Washington. This study included seven operators employed by the United Pacific Insurance Company and the Northwestern Mutual Life Insurance Company. A third study, undertaken concurrently with the second, was sponsored by the American Management Association. The study population included operators from Commonwealth Edison Company, Continental Illinois Bank and Trust Company of Chicago, Kraft Cheese Company, Montgomery Ward and Company, Sears, Roebuck and Company, and Jewel Tea Company, Inc.

Instructional classes were held for ten weeks, five days a week. During the first two weeks, two 1 1/2 hour instructional periods were held daily. For the latter eight weeks, a single 1 1/2 hour practice session was held daily.

The following collective findings and conclusions were presented:

1. After the initial two-week instructional practice period, retrainees returned to regular office production activities using the Dvorak keyboard. They were keyboarding at 50 to 67 percent of their preretraining Qwerty keyboard production rate. Several operators were as high as 82 percent.
2. Upon termination of these studies, a 15 percent increase in performance on 5- and 10-minute straight-copy timed writings was found by retraining on the Dvorak keyboard. Per retrainee gains ranged from 62 to 227 percent. Classroom practice ranged from 43.5 to 94 hours with an average of 61 hours.
3. Keyboard skill could be replaced and increased on the Dvorak keyboard in a short period of time.
4. Some retrainees regained and exceeded their office production rates before they had regained their straight-copy timed-writing rates.
5. Operators who had experienced both the Dvorak and Qwerty keyboards preferred the Dvorak method.

Stivers (1941) also commented on the results of the study conducted by the American Management Association reviewed above. He indicated that the six operators selected for retraining on the Dvorak keyboard in that study had to meet the following requirements:

1. Office production had for some time been regularly measured in lines or keystrokes.
2. Office production had leveled off to the extent that output did not vary more than 5 percent during the six months prior to retraining.

Table 2 indicates that 150 Average Keystrokes Per Minute (AKPM) on office production for the 12 weeks prior to beginning retraining was established for the retrainees on the Qwerty keyboard.

Instruction on the Dvorak keyboard was undertaken by the six retrainees at the Bryant Stratton Business College in Chicago. Instructional classes were held for ten weeks, five days a week. During the first two weeks, instruction was held from 8:30 to 10 a.m. and from 3:30 to 5 p.m. During these two weeks, the retrainees did no keyboarding in their offices. No indication was given in the study regarding time allowed for rest periods.

For the following eight weeks, the six retrainees received skill development instruction from 3:30 to 5 p.m. only. When not receiving instruction, the retrainees worked

TABLE 2. KEYBOARDING RATES (AKPM)
FOR STIVERS (1941) STUDY

Retrainee Number	Qwerty AKPM [a]	Dvorak AKPM [a]	% Increase AKPM
1	110	123	11.8
2	162	179	10.5
3	126	157	24.6
4	158	151	(4.5)
5	184	181	(1.6)
6	158	176	11.4
Average	150	162	8.7
			11.3[b]

[a] Average Keystrokes Per Minute (Office Production)
[b] Retrainee 4 excluded

on regular office tasks, using Dvorak keyboard typewriters. No record of actual minutes of office production keyboarding was kept.

The six participating companies kept weekly office production records on the retrainees for 45 weeks, beginning with the first week of total Dvorak keyboarding (third week of retraining). A high of 162 AKPM was attained by the retrainees as shown in Table 2.

The findings and conclusions of this research study were:

1. Four of the six retrainees surpassed their average Qwerty keyboard output by the end of 45 weeks of keyboarding (Table 2). Retrainee 4 did not progress as rapidly due to absence from work.
2. An 8.7 percent increase in productivity on the Dvorak keyboard was found for all six retrainees, while an 11.3 percent increase was found with Retrainee 4 excluded (Table 2).
3. All six retrainees were enthusiastic about the Dvorak keyboard and did not want to return to the Qwerty keyboard. The retrainees felt that they were much less fatigued at the end of the day using the Dvorak keyboard.

> From a purely humanitarian viewpoint, the reduction in operator fatigue may eventually prove sufficient cause to bring about the general adoption of the Dvorak keyboard and the retraining of operators. (Stivers, 1941:12)

A study by the U.S. Navy (1944) involved retraining 12 civil service keyboard operators on the Dvorak keyboard. These operators were selected from eight bureaus within the Navy Department, Washington, D.C., as being representative of civil service keyboard operators.

These operators had a preretraining Qwerty keyboard performance rate of 51 GWPM as shown in Table 3. Office

TABLE 3. KEYBOARDING RATES (GWPM) FOR U.S. NAVY (1944) STUDY

Retrainee Number	Qwerty[a] GWPM	Dvorak[a] GWPM	% Increase GWPM
1	37	60	62.2
2	49	61	24.5
3	59	77	30.5
4	55	64	16.4
5	52	57	9.6
6	44	63	43.2
7	51	53	3.9
8	68	78	14.7
9	51	59	15.7
10	42	56	33.3
11	38	49	28.9
12	56	62	10.7
Average	51	62	24.5

[a]10-minute straight-copy timed writing

production keyboarding rates before and during retraining instruction were not considered in this study.

The 12 retrainees received two hours of classroom instruction, six days a week, for eight weeks. They accumulated a total of 96 hours of instruction. Retrainee absence reduced the average classroom instruction period to 83 hours.

During the first two weeks of instruction, the retrainees undertook office tasks not involving keyboarding for the remaining six hours each day. For the following six weeks, however, the retrainees performed their regular office production keyboard activities using a Dvorak keyboard typewriter at their work station. Records were not kept regarding hours of office production keyboarding.

The findings and conclusions of this study were:

1. All 12 retrainees had surpassed their Qwerty keyboard GWPM performance rate by the end of the retraining program.
2. An average GWPM increase of 24.5 percent was found for the 12 retrainees on the Dvorak keyboard (Table 3).
3. The Dvorak keyboard was easy to learn, reduced errors, and caused less fatigue.

The study participants were retested eight to ten weeks after the formal retraining program was concluded. The results of this retesting indicated that some of the retrainees had increased their Dvorak keyboard skill through normal daily office production keyboarding.

Part II--Dvorak Keyboard Research, 1955-1957

A study by the U.S. General Services Administration (1956) involved the retraining of ten civil service keyboard operators on the Dvorak keyboard. These operators were

employed in different federal departments and agencies in Washington, D.C.

The U.S. Civil Service Commission tested the operators to determine their GWPM Qwerty keyboarding rate prior to beginning Dvorak keyboard retraining instruction. These retrainees averaged 72 GWPM on 1-minute timed writings and 55 GWPM on 5-minute timed writings as shown in Table 4. Office production data were not collected for these retrainees before or during retraining instruction.

Instruction on the Dvorak keyboard was undertaken by the retrainees at the office of the Personal Property Utility Division of the Federal Supply Service. Classes were held from 10 a.m. to 12 noon and from 1 to 3 p.m. five days a week. Short rest periods and a 15-minute break were allowed in each session. Instruction was held over a 13-week period. The study did not mention average classroom instruction time or consider retrainee absence. Both 1- and 5-minute straight-copy timed writings were given to the ten retrainees daily throughout the training period.

The following findings and conclusions were presented:

1. All ten retrainees had exceeded their Qwerty keyboard 1- and 5-minute timed-writing rates on the Dvorak keyboard by the end of the retraining program.

TABLE 4. KEYBOARDING RATES (GWPM) FOR U.S. GENERAL SERVICES ADMINISTRATION (1956) STUDY

Retrainee Number	Qwerty GWPM [a]	Qwerty GWPM [b]	Dvorak GWPM [a]	Dvorak GWPM [b]	% Increase GWPM (1-minute timed writing)	% Increase GWPM (5-minute timed writing)
1	45	36	89	60	97.8	66.7
2	76	66	114	81	50.0	22.7
3	78	55	90	60	15.4	9.1
4	62	50	107	71	72.6	42.0
5	60	52	83	54	38.3	3.8
6	94	70	99	74	5.3	5.7
7	81	52	82	55	1.2	5.8
8	83	65	112	87	34.9	33.8
9	74	52	84	59	13.5	13.5
10	65	51	95	61	46.2	19.6
Average	72	55	96	67	37.5	22.3

[a] 1-minute straight-copy timed writing
[b] 5-minute straight-copy timed writing

2. An average Dvorak keyboard performance increase of 37.5 percent was found for 1-minute timed writings (Table 4).
3. An average Dvorak keyboard performance increase of 22.3 percent was found for 5-minute timed writings (Table 4).
4. A larger study population should be used, thereby providing a better basis for an interpretation of results.

Part III--Dvorak Keyboard Research, 1970-present

A study by Western Electric (1973) involved the retraining of six keyboard operators on the Dvorak keyboard. These operators were employed at Western Electric Eastern Region Headquarters, Cockysville, Maryland.

Each operator was chosen for retraining based on being employed in an office position which would allow time for participation in classroom instruction sessions. Five-minute straight-copy timed writings were given to each retrainee, thereby determining a preretraining Qwerty keyboard rate of 71 GWPM as shown in Table 5.

The retrainees received instruction on the Dvorak keyboard in a training classroom at the Eastern Region Headquarters office. Instruction began with two 4-hour introductory class sessions followed by 56 daily 2-hour sessions for a total of 120 hours. The six retrainees

TABLE 5. KEYBOARDING RATES (GWPM) FOR WESTERN ELECTRIC (1973) STUDY

Retrainee Number	Qwerty GWPM[a]	Dvorak GWPM[a]	% Increase GWPM
1	78	86	10.3
2	70	75	7.1
3	70	71	1.4
4	78	73	(6.4)
5	56	56	---
6	69	71	2.9
Average	71	72	2.6
			4.3[b]

[a]5-minute straight-copy timed writing
[b]Retrainee 4 excluded

averaged 104 hours of instruction due to nonattendance at retraining sessions. Five-minute straight-copy timed writings were given to each retrainee after completion of 80, 100, and 120 hours of retraining instruction.

The retrainees used a Dvorak keyboard typewriter which was similar to the typewriter used in the training sessions to perform regular office activities at their work station during the remaining six hours each day. No record of hours of office production keyboarding was maintained.

The findings and conclusions of this study were:

1. Five of the six retrainees had equaled or exceeded their preretraining Qwerty keyboard timed-writing rate on the Dvorak keyboard by the end of the retraining project (Table 5).
2. An average GWPM increase of 2.6 percent was found for all six retrainees, while a 4.3 percent increase was found with Retrainee 4 excluded (Table 5).
3. The six retrainees experienced a definite reduction in fatigue by using the Dvorak keyboard.

Summary and Conclusions

The seven research studies reviewed in this chapter were designed to determine if retraining on the Dvorak keyboard would increase keyboard operator performance. Each of these studies found that operator performance had increased through retraining on the Dvorak keyboard. Other findings from these studies indicated that retraining on the Dvorak keyboard:

1. Could be accomplished in a short period of time.
2. Allowed for less operator fatigue and more enjoyable keyboarding.
3. Improved keyboarding accuracy.

The studies reviewed lacked variable control, from both a methodological and procedural standpoint, making it difficult to obtain viable information for conducting this study. Therefore, caution should be taken when drawing conclusions from these studies as a group or individually. The following variables were not uniform or addressed at all:

1. Instructor familiarity with principles of learning for Dvorak keyboard retraining.
2. Instructional methods used for Dvorak keyboard retraining.
3. Length of classroom instructional program (weeks, months).
4. Amount of classroom instruction received by each retrainee within a study.
5. Use of office production keyboarding for skill development.
6. Length of each classroom instruction session.
7. Rest periods during classroom instruction.
8. Amount of Dvorak keyboarding outside of class.
9. Type of keyboard equipment used.
10. Length of straight-copy timed writings.
11. Syllabic intensity of straight-copy timed writings.

12. Quantitative base indicating performance resulting from retraining (straight-copy timed writings or office production).
13. Participant selection procedure.
14. Demographic characteristics (age, intelligence quotient, dexterity, etc.).

Recognizing the limitations of the retraining studies reviewed in this chapter, this retraining project was designed to incorporate their strengths and alleviate their weaknesses. The procedures section of Chapter 3 outlines the methodological and procedural basis for this study, which was developed through three pilot studies involving retraining (reviewed in Chapter 3) and the above literature review.

III. PROCEDURES

This study was concerned with determining performance levels for Dvorak keyboard operators through retraining. Figure 2 outlines the two main study groups by type of keyboarding equipment used.

Group I	Group II
8 Retrainees	8 Retrainees
Cathode Ray Tube (CRT)	Element Correcting
Word Processors	Typewriters
(Electronic)	(Mechanical)

Each retrainee received 10 hours of keyboard introduction instruction, followed by 100 hours of skill-development keyboarding.

Figure 2. Dvorak keyboard study groups

Questions and Null Hypotheses

Based on the findings and conclusions of the Dvorak keyboard retraining studies reviewed in Chapter 2 and keyboarding equipment used in today's office environment, the following main questions were still unresolved:

1. Are operator performance rates on the Dvorak keyboard less than, equal to, or greater than operator performance rates on the Qwerty keyboard?

2. Can keyboard operators learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard?

Keyboard office production performance was included in only one study reviewed in Chapter 2, indicating that further research with this performance indicator was necessary. Keyboard straight-copy performance was analyzed in all studies reviewed. However, because of limited control of study variables, as indicated in the summary and conclusions section of Chapter 2, further investigation with this performance measure was also warranted.

Noncorrecting electric typewriters were used in one of the studies reviewed in Chapter 2. The remaining studies used manual typewriters. Keyboard equipment now used in the office environment includes element correcting electric typewriters and cathode ray tube (CRT) word processors.

Therefore, research is needed pertaining to both production and straight-copy Dvorak keyboard performance, with the use of element correcting typewriters and CRT word processors. The following three assessment areas were addressed in this study pertaining to these four areas of concern: CRT production, element production, and CRT/element straight copy.

For each of these three study assessment areas, the two main questions given above were addressed. Subquestions

relating to these two main questions are given below as they relate to the three assessment areas specifically. These subquestions are followed by null hypotheses where appropriate for statistical analysis.

CRT Production

Subquestion 1a. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are CRT operator production performance rates less than, equal to, or greater than operator preretraining performance rates on the Qwerty keyboard?

This subquestion, when translated into a testable form, is as follows:

Null Hypothesis. There is no significant difference in production timed-writing scores between the Qwerty keyboard and the Dvorak keyboard for CRT word processors.

Subquestion 2a. Can CRT keyboard operators learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard, with learning measured by production performance?

Null Hypothesis. There is no significant difference in Dvorak keyboard production timed-writing scores at 20-hour intervals for 100 hours of skill-development keyboarding on CRT word processors.

Subquestion 2b. What is the production rate of learning for CRT keyboard operators receiving retraining on the Dvorak keyboard?

Element Production

Subquestion 1b. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are element operator production performance rates less than, equal to, or greater than operator preretraining performance rates on the Qwerty keyboard?

Null Hypothesis. There is no significant difference in production timed-writing scores between the Qwerty keyboard and the Dvorak keyboard for element correcting typewriters.

Subquestion 2c. Can element keyboard operators learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard, with learning measured by production performance?

Null Hypothesis. There is no significant difference in Dvorak keyboard production timed-writing scores at 25-hour intervals for 100 hours of skill-development keyboarding on element correcting typewriters.

Subquestion 2d. What is the production rate of learning for element keyboard operators receiving retraining on the Dvorak keyboard?

CRT/Element Straight Copy

Subquestion 1c. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are CRT operator straight-copy performance rates less than, equal to, or greater than operator preretraining performance rates on the Qwerty keyboard?

Null Hypothesis. There is no significant difference in straight-copy timed-writing scores between the Qwerty keyboard and the Dvorak keyboard for CRT word processors.

Subquestion 1d. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are element operator straight-copy performance rates less than, equal to, or greater than operator preretraining performance rates on the Qwerty keyboard?

Null Hypothesis. There is no significant difference in straight-copy timed-writing scores between the Qwerty keyboard and the Dvorak keyboard for element correcting typewriters.

Subquestion 2e. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are CRT operator straight-copy performance rates different from element operator straight-copy performance rates?

Null Hypothesis. There is no significant difference in Dvorak keyboard straight-copy timed-writing scores between CRT word processors and element correcting typewriters over 100 hours of skill-development keyboarding.

Subquestion 2f. Can CRT/element operators learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard, with learning measured by straight-copy performance?

Null Hypothesis. There is no significant difference in Dvorak keyboard straight-copy timed-writing scores at 10-hour intervals for 100 hours of skill-development keyboarding on CRT word processors and element correcting typewriters.

Subquestion 2g. Is interaction present between CRT operator straight-copy performance on the Dvorak keyboard and element operator straight-copy performance on the Dvorak keyboard?

Null Hypothesis. There is no significant interaction in Dvorak keyboard straight-copy timed-writing scores between time and equipment during 100 hours of skill-development keyboarding.

Subquestion 2h. What is the straight-copy rate of learning for CRT/element keyboard operators receiving retraining on the Dvorak keyboard?

Selection of the Participants

A request for study participants was published in the July 1977 through October 1977 monthly newsletters of the Willamette Valley Chapter of the International Word Processing Association. Responses came from public and private sector employers in Portland, Salem, Corvallis, and Eugene, Oregon. All keyboard operators volunteering to undertake Dvorak keyboard retraining from these agencies and

and organizations were included in the study. No attempt was made to select study participants randomly.

Design of the Study

The instructional procedures used in this research project were developed as a result of three pilot studies conducted from March to September 1977 by the researcher and from a review of prior retraining studies found in Chapter 2. The three pilot studies are reviewed below.

Pilot Study 1. Eight business education and administrative office management students at Oregon State University were included in the first pilot study during the spring 1977 academic quarter. The following purposes were addressed in this pilot study:

1. To determine keyboard operator straight-copy rate of learning on the Dvorak keyboard over an extended period of time.
2. To determine the straight-copy keyboarding rate at which production correspondence could be successfully undertaken.
3. To determine if Dvorak keyboard skill could be attained through individualized instruction.

Each retrainee received individualized instruction over an eight-week period. All retrainees used only the Dvorak keyboard during this period. Six hours of keyboard introduction instruction were completed by each retrainee,

followed by additional skill-development drill exercise and production correspondence keyboarding during the remaining portion of the pilot study.

The findings of this pilot study were:

1. The straight-copy rate of learning on the Dvorak keyboard was 1 word per minute per hour of keyboarding.
2. A straight-copy Dvorak keyboard rate of 35 to 40 words per minute was found to be necessary to undertake production correspondence successfully.
3. Dvorak keyboard skill could be successfully attained through individualized instruction.

Pilot Study 2. The second pilot study included 19 in-service high school and community college business education instructors enrolled in a word processing workshop at Oregon State University during the 1977 summer session.

The purposes of this pilot study were:

1. To determine if production correspondence keyboarding could be used for Dvorak keyboard skill development.
2. To determine if Dvorak keyboard skill could be attained through group instruction.

3. To determine an appropriate practice period length for initial Dvorak keyboard introduction instruction.

The retrainees received 15 hours of skill-development instruction on the Dvorak keyboard. The first five hours involved keyboard introduction instruction. The following ten hours involved keyboard reinforcement through the use of production correspondence practice materials (letters, manuscripts, tables, etc.) with some skill-development exercise drill included. All retrainees used only the Dvorak keyboard during the retraining period.

The findings of this pilot study were:

1. Production correspondence keyboarding was found to be an efficient means of Dvorak keyboard skill development when used as a supplement to an organized skill-development exercise program. Production correspondence of a continuous-copy nature, such as letters and manuscripts, was found to be most beneficial for developing Dvorak keyboarding skill.
2. Dvorak keyboarding skill could be attained successfully through group instruction.
3. Short practice periods of 15 minutes were found to be most appropriate for initial Dvorak keyboard skill development.

Pilot Study 3. The third pilot study involved retraining 32 business education and administrative office management students enrolled in an administrative office management office systems course at Oregon State University during the fall 1977 academic quarter.

The following purposes were addressed in this pilot study:

1. To determine if a straight-copy Dvorak keyboard rate of 35 to 40 words per minute could be attained in ten hours of keyboard introduction instruction.
2. To determine if short practice periods of 15 minutes were effective for keyboard introduction instruction on the Dvorak keyboard.
3. To determine if a keyboard operator could move back and forth between the Dvorak keyboard and the Qwerty keyboard during ten hours of keyboard introduction instruction on the Dvorak keyboard.

All retrainees received ten hours of group instruction on the Dvorak keyboard over a three-week period. The first four hours involved keyboard introduction instruction, while the following six hours involved initial keyboard skill-development exercises. Each retrainee was involved in a 55-minute classroom session daily, which included three 15-minute keyboarding sessions with a 5-minute rest period

between sessions. All retrainees used the Dvorak keyboard during the daily practice sessions only and used the Qwerty keyboard for all other keyboarding activities for the three-week duration of the pilot study. Each retrainee was required to use the Qwerty keyboard for at least 15 minutes between daily Dvorak keyboard classroom sessions.

The findings of this pilot study were:

1. A straight-copy Dvorak keyboard rate of 37 words per minute was obtained after ten hours of keyboard introduction instruction.
2. Practice sessions of 15 minutes in length were found to be quite effective for keyboard introduction instruction on the Dvorak keyboard.
3. Keyboard operators could operate the Dvorak keyboard and the Qwerty keyboard interchangeably during ten hours of keyboard introduction instruction.

The formal study began in September 1977 and ran through March 1978. Study participants did not start and end retraining at the same time within this period. The Dvorak Keyboard, shown in Figure 1, was used in this study.

The procedures used for conducting both the keyboard introduction and skill development segments of the main study are outlined below.

Keyboard Introduction--10 Hours. The following procedures were followed in conducting the keyboard introduction segment of this study:

1. Ten hours of keyboard introduction instruction were given to each of the retrainees. The first four hours involved an introduction to the keyboard, with the following six hours involving keyboarding reinforcement. The Qwerty keyboard was used by each retrainee for office production activities when the retrainee was not involved in Dvorak keyboard practice sessions.

2. Each of the retrainees completed this segment of instruction on an individual basis. The researcher worked with each retrainee on the first day of retraining, aiding the retrainee in developing a constructive approach to learning the keyboard. Weekly follow-up visitations were made by the researcher to check the progress of each retrainee.

3. This segment of the retraining program continued over a period of two to three weeks. Fifteen 45-minute periods of individualized instruction were completed during this period. The retrainee had the option of completing either one or two periods of instruction each day based on office workload. Each period of instruction included three 15-minute blocks of keyboard practice with 5-minute rest periods between blocks. The use of short learning periods

was suggested by Douglas (1973) in that they are more effective in the development of initial keyboard skill.

Keyboard introduction and reinforcement drills were designed by the researcher for use by the retrainees during each Dvorak keyboard practice session. These drills were developed in that instructional materials were not available for Dvorak keyboard retraining.

4. All introductory Dvorak keyboard practice took place on an element typewriter (converted to the Dvorak keyboard) provided by the retrainee's employer. Qwerty keyboard office production was keyboarded on the type of equipment (element or CRT) at the retrainee's work station.

5. Two 3-minute Qwerty keyboard straight-copy timed writings were taken by each retrainee before retraining began. These timed writings had a 1.25 to 1.50 syllabic intensity range. All straight-copy timed writings used in this study were from Hansen and Skaff (1976). Atwood (1965) indicated that the optimum duration for a straight-copy timed writing was three minutes. He also mentioned that timed-writing copy with high syllabic intensity enables the keyboard operator to exert the utmost effort and concentration.

Performance on straight-copy timed writings taken during the course of the research project was measured in GWPM. An error limit of two words per minute was set for these straight-copy timed writings. Palmer (1977) and

Russon and Wanous (1973) have indicated that the GWPM performance score, with a preset error limit, was one of the best measures of straight-copy keyboard performance. West (1969) stated that an error limit of no fewer than two errors per minute should be required for straight-copy timed writings. Both students and office workers average two errors per minute of keyboarding.

6. A completion-time Qwerty keyboard production timed writing was taken by each CRT retrainee before retraining began. This timed writing involved keyboarding, adjusting, proofreading, and correcting a 300-word manuscript (Hansen and Skaff, 1976) in the shortest time possible by the retrainee. This timed writing had a 1.35 to 1.50 syllabic intensity range.

7. A 15-minute Qwerty keyboard production timed writing was taken by each element retrainee before retraining began. This timed writing involved keyboarding, proofreading, and correcting a series of letters of varying lengths within the 15-minute time limit. These letters had a 1.25 to 1.50 syllabic intensity range. All preretraining Qwerty keyboard timed writings (straight-copy and production) were administered by the researcher.

Different production timed writings were given to the CRT and element retrainee groups to duplicate the type of office production keyboarding undertaken by each group.

Skill Development--100 Hours. The procedures below were followed in conducting the skill development segment of this study:

1. One hundred hours of skill-development keyboarding were undertaken by each retrainee in this segment of the study. Each retrainee used the Dvorak keyboard exclusively for all keyboarding activities.

2. Each day, 20 minutes were devoted to Dvorak keyboard skill-development exercise practice, with office production activities comprising the remaining daily Dvorak keyboarding. Skill-development exercise practice was combined with office production activity for attainment of the 100 hours of skill-development keyboarding. Dvorak keyboard skill-development drills were developed by the researcher for use by the retrainees during each skill-development practice session.

Dvorak keyboard skill was developed through daily skill-development practice exercises and actual office production. A log was kept by each retrainee for recording actual keyboarding time spent with each production activity. Palmer (1977) and Duncan (1967) have indicated that a definite, organized skill-building program serves as the foundation for skill development. Office production activities reinforce the skill-building program and add greatly to keyboard skill development.

3. Two 3-minute Dvorak keyboard straight-copy timed writings were taken by each retrainee after each ten hours of Dvorak keyboarding. This time factor included both office production and skill-development exercise as indicated above. These timed writings had a 1.25 to 1.50 syllabic intensity.

4. A completion-time Dvorak keyboard production timed writing was taken by each CRT retrainee after completion of 20, 40, 60, 80, and 100 hours of keyboarding. These timed writings had a 1.35 to 1.50 syllabic intensity range.

5. A 15-minute Dvorak keyboard production timed writing was taken by each element retrainee after completion of 25, 50, 75, and 100 hours of keyboarding. These timed writings had a 1.35 to 1.50 syllabic intensity range. All timed writings (straight-copy and production) taken during this segment of the study were administered by the researcher or office supervisory personnel.

The Qwerty and Dvorak keyboard production and straight-copy timed-writing scores mentioned above comprised the data used for statistical analysis in this study.

Statistical Analysis

The following four statistical measures were used to address the subquestions of this study and their related null hypotheses.

t Test. The t test was used to test the null hypotheses for Subquestions 1a, 1b, 1c, and 1d at the .05 level of significance (Runyon and Haber, 1971).

One-Factor Analysis of Variance with Repeated Measures. One-factor analysis of variance with repeated measures was used to test the null hypotheses for Subquestions 2a and 2c at the .05 level of significance (Winer, 1962).

Two-Factor Analysis of Variance with Repeated Measures. Two-factor analysis of variance with repeated measures was used to test the null hypotheses for Subquestions 2e, 2f, and 2g at the .05 level of significance (Winer, 1962).

Acceptance or rejection of these nine null hypotheses was based on analysis of data through the statistical measures identified above.

Trend Analysis. Trend analysis was used to address Subquestions 2b, 2d, and 2h (Winer, 1962).

IV. FINDINGS

The purpose of this study was to provide information pertaining to performance levels for Dvorak keyboard operators through retraining. The following two main questions were addressed in this study:

1. Are operator performance rates on the Dvorak keyboard less than, equal to, or greater than operator performance rates on the Qwerty keyboard?
2. Can keyboard operators learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard?

Sixteen keyboard operators were included in this study, eight using CRT word processors and eight using element correcting typewriters to perform office production activities. Each retrainee compiled 100 hours of Dvorak skill-development keyboarding during the study, with both production and straight-copy timed writings being given periodically to assess performance through retraining. These performance scores comprised the data used in addressing subquestions for the two main study questions.

These subquestions related to the following three assessment areas: CRT production, element production, and CRT/element straight copy. Subquestions, related

hypotheses, and findings for these three assessment areas are presented below.

CRT Production

Subquestion 1a. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are CRT operator production performance rates less than, equal to, or greater than operator preretraining performance rates on the Qwerty keyboard?

Null Hypothesis. There is no significant difference in production timed-writing scores between the Qwerty keyboard and the Dvorak keyboard for CRT word processors.

The purpose of this null hypothesis was to determine whether or not CRT Dvorak keyboard production rates, after 100 hours of skill-development keyboarding, were significantly different from preretraining Qwerty keyboard production rates.

The t test was used to determine if a difference existed at the .05 level of significance. As indicated in Table 6, this null hypothesis was accepted ($t = 1.31$, $ndf = 7$, $p > .05$). A significant difference was not found between preretraining Qwerty keyboard production rates and Dvorak keyboard production rates after 100 hours of skill-development keyboarding.

Subquestion 2a. Can CRT keyboard operators learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard, with learning measured by production performance?

Null Hypothesis. There is no significant difference in Dvorak keyboard production timed-writing scores at 20-hour intervals for 100

TABLE 6. T TEST OF CRT WORD PROCESSOR PRODUCTION RATES ON QWERTY AND DVORAK KEYBOARDS (N_{CRT} = 8)

Keyboard	Mean	Standard Deviation	t
Qwerty	51.38	9.97	1.31[a]
Dvorak	57.38	7.05	

[a] $p > .05$

hours of skill-development keyboarding on CRT word processors.

The purpose of this null hypothesis was to determine whether or not a statistically significant increase in production rate of learning was present for CRT retrainees on the Dvorak keyboard at 20-hour intervals for 100 hours of Dvorak skill-development keyboarding.

One-factor analysis of variance with repeated measures was used to determine if a difference existed at the .05 level of significance. Table 7 indicates that this null hypothesis was rejected ($F = 97.42$, $ndf = 4,28$, $p < .05$). A significant change in production rate of learning was present over 100 hours of skill-development keyboarding. Table 8 gives the group means and standard deviations for production timed-writing scores after every 20 hours of skill-development keyboarding, which were used in the statistical analysis to indicate rate of learning.

TABLE 7. ANALYSIS OF VARIANCE WITH REPEATED MEASURES OF CRT WORD PROCESSOR PRODUCTION RATES ON THE DVORAK KEYBOARD OVER 100 HOURS OF SKILL-DEVELOPMENT KEYBOARDING MEASURED AT 20-HOUR INTERVALS (N_{CRT} = 8)

Source of Variation	SS	df	MS	F
Between Retrainees	1,056.70	7		
Within Retrainees	2,990.80	32		
Time	2,790.25	4	697.56	97.42[a]
Residual	200.55	28	7.16	
Total	4,047.50	39		

[a] $p < .05$

TABLE 8. MEAN AND STANDARD DEVIATION SCORES OF CRT WORD PROCESSOR PRODUCTION RATES

	Hours of Keyboarding					
	20	40	60	80	100	Total
Mean	33.50	40.50	45.63	51.75	57.38	45.75
Standard Deviation	5.63	4.18	5.05	5.63	7.05	5.14

Subquestion 2b. What is the production rate of learning for CRT keyboard operators receiving retraining on the Dvorak keyboard?

Trend analysis was used to determine if the CRT production rate of learning was linear or quadratic in nature.

Table 9 indicates that the CRT production rate of learning was linear at the .05 level of significance ($F = 388.94$, $ndf = 1,28$, $p < .05$).

TABLE 9. TREND ANALYSIS OF CRT WORD PROCESSOR PRODUCTION RATES OVER 100 HOURS OF SKILL-DEVELOPMENT KEYBOARDING AT 20-HOUR INTERVALS

	SS	C	MS	F
Linear	10	474	2,784.80	388.94[a]
Quadratic	14	-14	1.75	.24

[a] $p < .05$

Figure 3 presents the linear regression line indicating production rate of learning for the eight CRT retrainees. The linear equation used to derive the regression line is also given ($Y_c = 28.05 + .30X$).

Element Production

Subquestion 1b. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are element operator production performance rates less than, equal to, or greater than operator preretraining performance rates on the Qwerty keyboard?

Null Hypothesis. There is no significant difference in production timed-writing scores between the Qwerty keyboard and the Dvorak keyboard for element correcting typewriters.

The purpose of this null hypothesis was to determine whether or not element Dvorak keyboard production rates

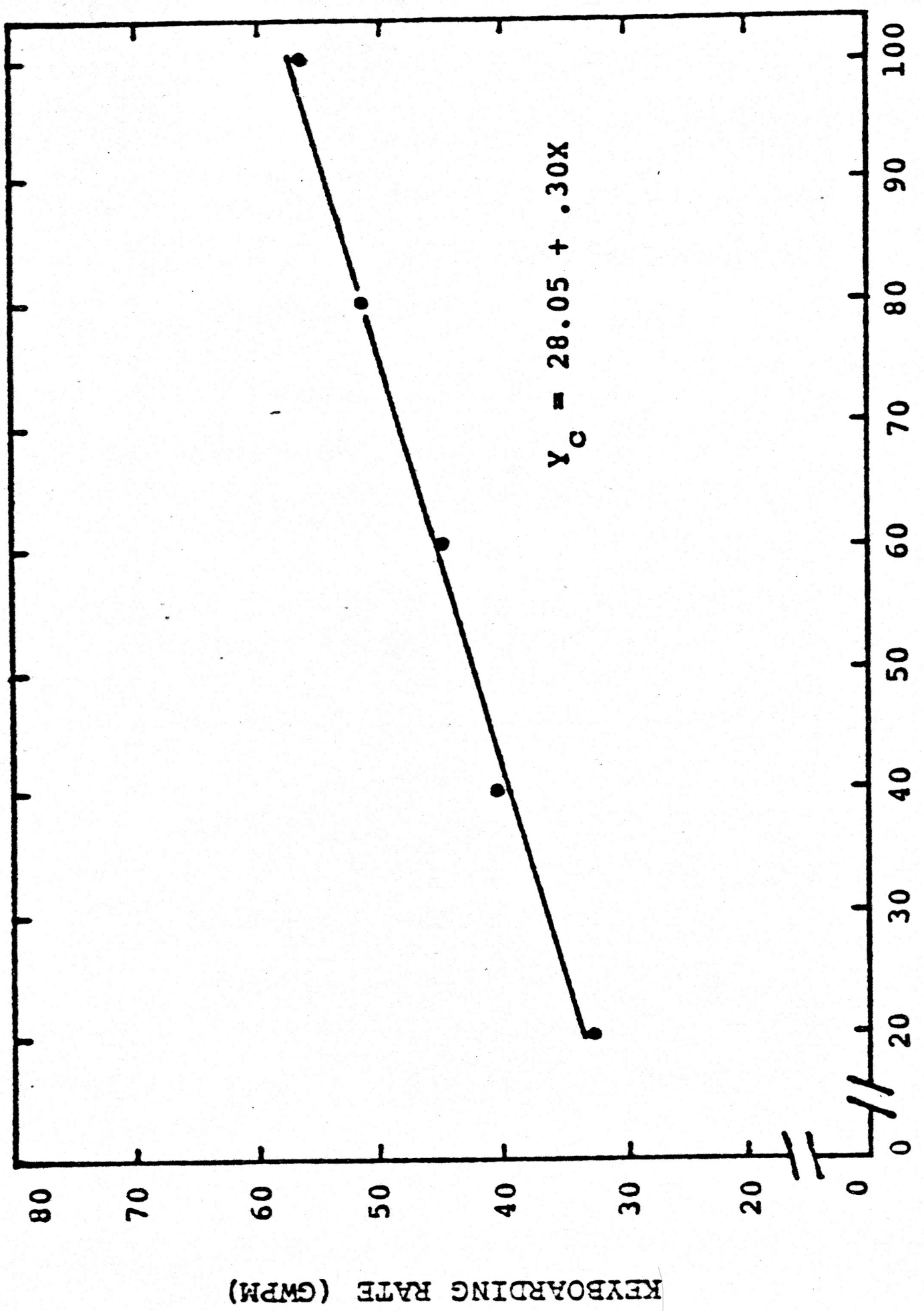

Figure 3. Dvorak keyboard production rate of learning on CRT word processors at 20-hour intervals for 100 hours of skill-development keyboarding

after 100 hours of Dvorak skill-development keyboarding were significantly different from preretraining Qwerty keyboard production rates.

The t test was used to determine if a difference existed at the .05 level of significance. As indicated in Table 10, this null hypothesis was accepted ($t = 1.62$, $ndf = 7$, $p > .05$). A significant difference was not found between preretraining Qwerty keyboard production rates and Dvorak keyboard production rates after 100 hours of skill-development keyboarding.

TABLE 10. T TEST OF ELEMENT CORRECTING TYPEWRITER PRODUCTION RATES ON QWERTY AND DVORAK KEYBOARDS ($N_E = 8$)

Keyboard	Mean	Standard Deviation	t
Qwerty	40.25	5.45	1.62[a]
Dvorak	47.00	9.55	

[a] $p > .05$

Subquestion 2c. Can element keyboard operators learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard, with learning measured by production performance?

Null Hypothesis. There is no significant difference in Dvorak keyboard production timed-writing scores at 25-hour intervals for 100 hours of skill-development keyboarding on element correcting typewriters.

The purpose of this null hypothesis was to determine whether or not a statistically significant increase in production rate of learning was present for element retrainees on the Dvorak keyboard at 25-hour intervals for 100 hours of skill-development keyboarding.

One-factor analysis of variance with repeated measures was used to determine if a difference existed at the .05 level of significance. Table 11 indicates that this null hypothesis was rejected ($F = 24.44$, $ndf = 3,21$, $p < .05$). A significant change in production rate of learning was present over 100 hours of Dvorak skill-development keyboarding. Table 12 gives the group means and standard deviations for production timed-writing scores after every 25 hours of skill-development keyboarding, which were used in the statistical analysis to indicate rate of learning.

Subquestion 2d. What is the production rate of learning for element keyboard operators receiving retraining on the Dvorak keyboard?

Trend analysis was used to determine if the element production rate of learning was linear or quadratic in nature. Table 13 indicates that the element production rate of learning was linear at the .05 level of significance ($F = 71.84$, $ndf = 1,21$, $p < .05$).

Figure 4 presents the linear regression line indicating production rate of learning for the eight element retrainees. The linear equation used to derive the regression line is also given ($Y_c = 28.31 + .19X$).

TABLE 11. ANALYSIS OF VARIANCE WITH REPEATED MEASURES OF ELEMENT CORRECTING TYPEWRITER PRODUCTION RATES ON THE DVORAK KEYBOARD OVER 100 HOURS OF SKILL-DEVELOPMENT KEYBOARDING MEASURED AT 25-HOUR INTERVALS (N_E = 8)

Source of Variation	SS	df	MS	F
Between Retrainees	1,696.37	7		
Within Retrainees	1,135.50	24		
Time	882.62	3	294.21	24.44[a]
Residual	252.88	21	12.04	
Total	2,831.87	31		

[a] $p < .05$

TABLE 12. MEAN AND STANDARD DEVIATION SCORES OF ELEMENT CORRECTING TYPEWRITER PRODUCTION RATES

	Hours of Keyboarding				
	25	50	75	100	Total
Mean	33.63	36.38	42.75	47.00	39.94
Standard Deviation	6.40	5.65	8.88	9.55	7.28

CRT/Element Straight Copy

Subquestion 1c. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are CRT operator straight-copy performance rates less than, equal to, or greater than operator preretraining performance rates on the Qwerty keyboard?

TABLE 13. TREND ANALYSIS OF ELEMENT CORRECTING TYPEWRITER PRODUCTION RATES OVER 100 HOURS OF SKILL-DEVELOPMENT KEYBOARDING AT 25-HOUR INTERVALS

	SS	C	MS	F
Linear	20	372	864.90	71.84[a]
Quadratic	4	12	4.50	.37

[a] $p < .05$

Null Hypothesis. Tnere is no significant difference in straight-copy timed-writing scores between the Qwerty keyboard and the Dvorak keyboard for CRT word processors.

Subquestion 1d. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are element operator straight-copy performance rates less than, equal to, or greater than operator preretraining performance rates on the Qwerty keyboard?

Null Hypothesis. There is no significant difference in straight-copy timed-writing scores between the Qwerty keyboard and the Dvorak keyboard for element correcting typewriters.

The purpose of these two null hypotheses was to determine whether or not Dvorak keyboard straight-copy rates after 100 hours of skill-development keyboarding were significantly different from preretraining Qwerty keyboard straight-copy rates.

A separate group t test was used for the CRT and element retrainee groups to determine if a difference existed at the .05 level of significance. The null hypothesis for Subquestion 1c (CRT) was accepted as

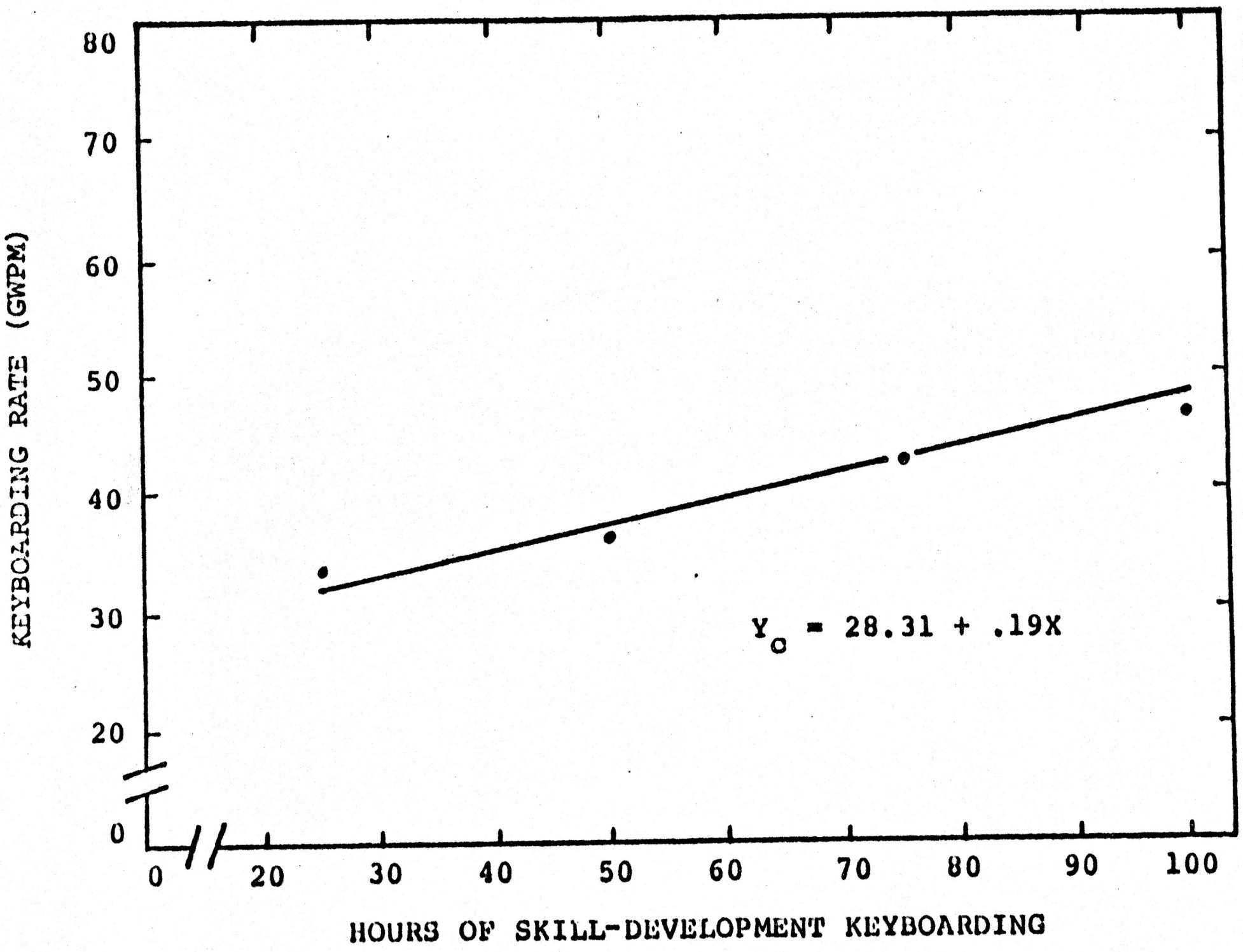

Figure 4. Dvorak keyboard production rate of learning on element correcting typewriters at 25-hour intervals for 100 hours of skill-development keyboarding

indicated in Table 14 ($t = 1.42$, $ndf = 7$, $p > .05$). The null hypothesis for Subquestion 1d (element) was accepted as shown in Table 15 ($t = .77$, $ndf = 7$, $p > .05$). Dvorak keyboard straight-copy rates, after 100 hours of skill-development keyboarding, were not found to be significantly different from preretraining Qwerty keyboard straight-copy rates.

TABLE 14. T TEST OF CRT WORD PROCESSOR STRAIGHT-COPY RATES ON QWERTY AND DVORAK KEYBOARDS ($N_{CRT} = 8$)

Keyboard	Mean	Standard Deviation	t
Qwerty	77.75	8.58	1.42[a]
Dvorak	71.88	6.70	

[a] $p > .05$

TABLE 15. T TEST OF ELEMENT CORRECTING TYPEWRITER STRAIGHT-COPY RATES ON QWERTY AND DVORAK KEYBOARDS ($N_E = 8$)

Keyboard	Mean	Standard Deviation	t
Qwerty	70.88	10.34	.77[a]
Dvorak	73.13	11.37	

[a] $p > .05$

Subquestion 2e. After 100 hours of skill-development keyboarding on the Dvorak keyboard, are CRT operator straight-copy performance rates different from element operator straight-copy performance rates?

> Null Hypothesis. There is no significant difference in Dvorak keyboard straight-copy timed-writing scores between CRT word processors and element correcting typewriters over 100 hours of skill-development keyboarding.

Subquestion 2f. Can CRT/element operators learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard, with learning measured by straight-copy performance?

> Null Hypothesis. There is no significant difference in Dvorak keyboard straight-copy timed-writing scores at ten-hour intervals for 100 hours of skill-development keyboarding on CRT word processors/element correcting type-typewriters.

Subquestion 2g. Is interaction present between CRT operator straight-copy performance on the Dvorak keyboard and element operator straight-copy performance on the Dvorak keyboard?

> Null Hypothesis. There is no significant interaction in Dvorak keyboard straight-copy timed-writing scores between time and equipment during 100 hours of skill-development keyboarding.

The purpose of the null hypothesis for Subquestion 2e was to determine whether or not a statistically significant difference in straight-copy timed-writing scores was present between CRT retrainees and element retrainees over 100 hours of Dvorak skill-development keyboarding. The null hypothesis for Subquestion 2f indicated whether or not a significant difference in straight-copy timed-writing scores over 100 hours of Dvorak skill-development keyboarding was present, regardless of type of equipment used by retrainees.

The null hypothesis for Subquestion 2g indicated whether or not significant interaction in straight-copy timed-writing scores between time and equipment was present during 100 hours of Dvorak skill-development keyboarding.

Two-factor analysis of variance with repeated measures was used to test the three null hypotheses above at the .05 level of significance. Table 16 indicates that the null hypothesis for Subquestion 2e was accepted ($F = .08$, $ndf = 1,14$, $p > .05$). No significant difference was found between the straight-copy scores of CRT retrainees and the straight-copy scores of element retrainees.

The null hypothesis for Subquestion 2f was rejected, as indicated in Table 16 ($F = 149.03$, $ndf = 9,126$, $p < .05$). A significant difference in straight-copy timed-writing scores was found at 10-hour intervals for 100 hours of Dvorak skill-development keyboarding.

Table 16 also indicates that the null hypothesis for Subquestion 2g was accepted ($F = .66$, $ndf = 9,126$, $p > .05$). Significant interaction was not found between time and equipment during 100 hours of Dvorak skill-development keyboarding. Table 17 presents the means and standard deviations for straight-copy timed-writing scores after every 10 hours of Dvorak skill-development keyboarding.

Subquestion 2h. What is the straight-copy rate of learning for CRT/element keyboard operators receiving retraining on the Dvorak keyboard?

TABLE 16. TWO-FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON ONE FACTOR ON STRAIGHT-COPY RATES BY EQUIPMENT (CRT AND ELEMENT) AND AMOUNT OF SKILL-DEVELOPMENT KEYBOARDING (IN 10-HOUR INCREMENTS TO 100 HOURS) ($N_{CRT} = 8$, $N_E = 8$)

Source of Variance	SS	df	MS	F
Between Retrainees	10,588.90	15		
A (Equipment)	57.60	1	57.60	.08
Retrainees Within Groups	10,531.30	14	752.24	
Within Groups	18,886.20	144		
B (Time)	17,194.98	9	1,910.55	149.03[a]
AB	76.52	9	8.50	.66
B x Retrainees Within Groups	1,614.70	126	12.82	

[a] $p < .05$

Trend analysis was used to determine if the straight-copy rate of learning was linear, quadratic, or cubic in nature. Retrainees using both CRT and element equipment were grouped together in this analysis, based on the acceptance of the null hypothesis for Subquestion 2e in which no significant difference in straight-copy timed-writing scores was found between the two equipment groups. Table 18 indicates that the straight-copy rate of learning was quadratic

TABLE 17. MEAN AND STANDARD DEVIATION SCORES OF CRT WORD PROCESSOR/ ELEMENT CORRECTING TYPEWRITER STRAIGHT-COPY RATES

	HOURS OF KEYBOARDING										
	10	20	30	40	50	60	70	80	90	100	Total
CRT Mean	39.25	45.50	50.63	54.50	59.38	60.50	64.00	65.63	68.50	71.88	57.98
CRT Standard Deviation	6.22	7.53	7.10	7.65	9.09	8.97	6.95	7.27	7.23	6.70	7.00
Element Mean	39.50	45.75	49.13	55.00	60.38	63.50	65.38	68.25	71.75	73.13	59.18
Element Standard Deviation	6.52	8.10	7.87	10.58	9.31	10.40	10.42	10.86	10.71	11.37	9.09
Total Mean	39.38	45.63	49.88	54.75	59.88	62.00	64.69	66.94	70.13	72.50	58.58
Total Standard Deviation	6.34	7.80	7.53	9.24	9.21	9.83	8.88	9.33	9.24	9.39	8.14

at the .05 level of significance (F = 34.68, ndf = 1,135, $p < .05$).

TABLE 18. TREND ANALYSIS OF CRT WORD PROCESSOR/ELEMENT CORRECTING TYPEWRITER STRAIGHT-COPY RATES OVER 100 HOURS OF SKILL-DEVELOPMENT KEYBOARDING AT 10-HOUR INTERVALS

	SS	C	MS	F
Linear	330	9,390	16,699.26	1,332.74[a]
Quadratic	132	-958	434.55	34.68[a]
Cubic	8,580	1,880	25.75	2.06

[a] $p < .05$

Figure 5 presents the curvilinear regression line indicating straight-copy rate of learning for the 16 CRT/element retrainees. The quadratic equation used to derive the regression line is also given ($Y_c = 34.0 + .6066X - .0023X^2$).

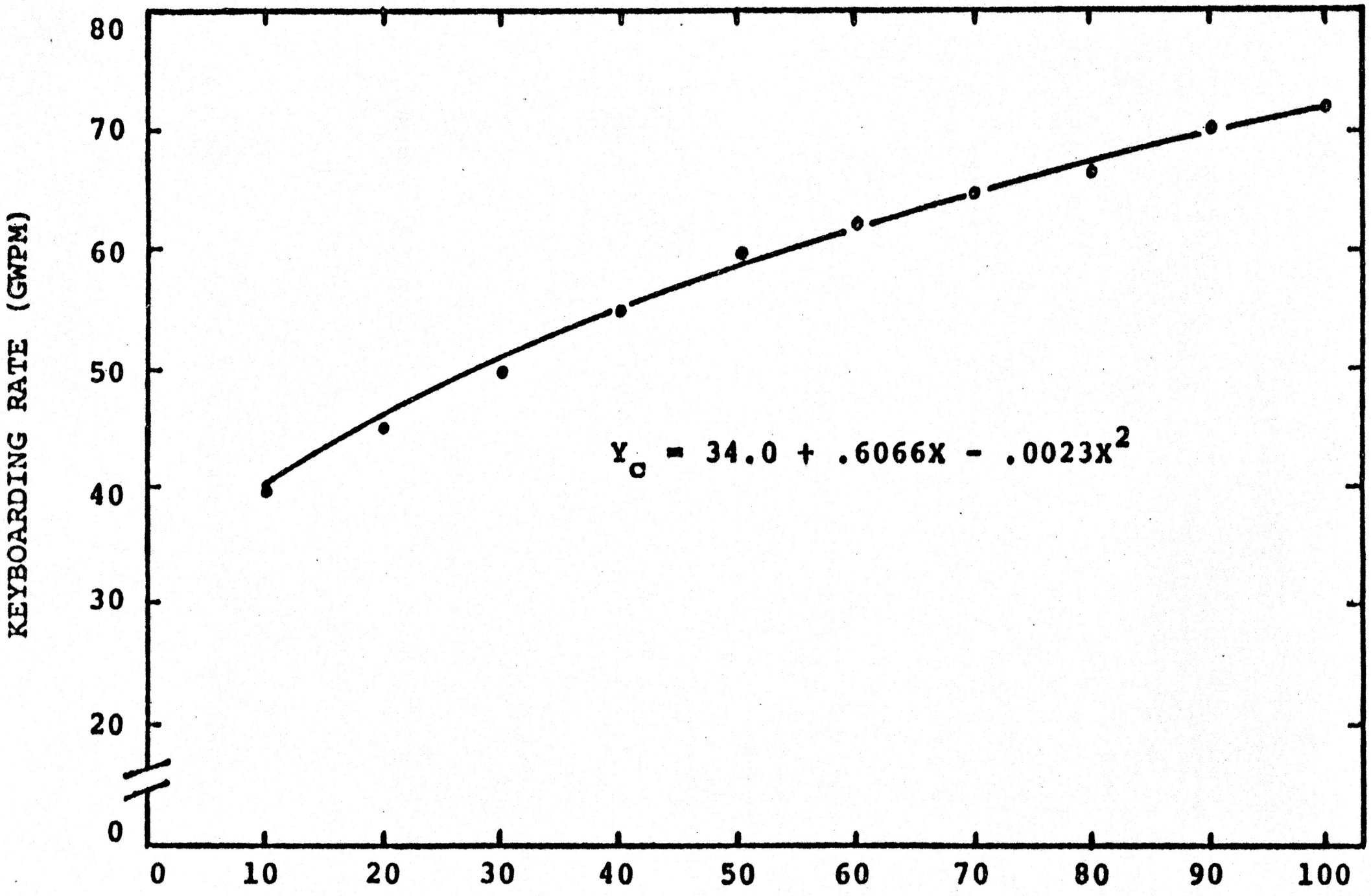

Figure 5. Dvorak keyboard straight-copy rate of learning on CRT word processors/element correcting typewriters at 10-hour intervals for 100 hours of skill-development keyboarding

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to provide information pertaining to office production performance levels by Dvorak keyboard operators. The following two main questions were addressed in the study:

1. Are operator performance rates on the Dvorak keyboard less than, equal to, or greater than operator performance rates on the Qwerty keyboard?
2. Can keyboard operators learn to use the Dvorak keyboard if they were initially trained to use the Qwerty keyboard?

Procedures

The participants in this research study included 16 keyboard operators employed in public and private sector agencies and organizations in Oregon. Eight operators used CRT word processors and eight used element correcting typewriters. Each participant received ten hours of keyboard introduction instruction on the Dvorak keyboard, followed by 100 hours of skill development keyboarding involving both skill-development drill exercise and daily office production correspondence.

Nine null hypotheses were developed regarding Dvorak keyboard retraining rates. The t test and one- and two-factor analysis of variance with repeated measures were used to test these null hypotheses. Trend analysis was also used to describe the data.

Discussion of Findings

An examination of the data and learning curves in this study revealed that there were several areas which required further clarification and discussion. These areas were:

1. Preretraining Qwerty keyboard versus Dvorak keyboard production and straight-copy rates after 100 hours of skill-development keyboarding on CRT and element keyboarding equipment.

2. Production and straight-copy rates of learning for CRT and element keyboarding equipment.

Preretraining Qwerty versus Ending Dvorak

Significant differences at the .05 level were not found between preretraining Qwerty keyboard production and straight-copy rates and Dvorak keyboard production and straight-copy rates after 100 hours of skill-development keyboarding on both CRT and element keyboarding equipment. Although a significant difference was not found, Dvorak keyboard production performance rates were an average of 12 and 17 percent greater than preretraining Qwerty keyboard

production performance rates on CRT and element keyboarding equipment, respectively. The percentage increase or decrease in straight-copy rates was not sizable for either CRT or element keyboarding equipment.

Rate of Learning

The trend analysis statistic indicated that production performance rates were linear at the end of 100 hours of skill-development keyboarding on CRT and element keyboarding equipment. There was no indication of plateauing during the 100 hours of skill development keyboarding. The straight-copy performance rate, on the other hand, was curvilinear, indicating that straight-copy rates were tapering off during 100 hours of skill development keyboarding.

The regression lines indicated that both production and straight-copy performance rates would continue upward beyond 100 hours of skill-development keyboarding. If this were true, the difference between preretraining Qwerty keyboard and ending Dvorak keyboard rates (previously mentioned) could be significant at some future point.

Conclusions

1. Dvorak keyboard production rates, after 100 hours of skill-development keyboarding, were not significantly greater than preretraining Qwerty keyboard production rates for both CRT and element keyboarding equipment. It should

be noted that production performance increased 12 and 17 percent on CRT and element keyboarding equipment, respectively, as addressed in the Discussion of Findings.

2. Dvorak keyboard straight-copy rates, after 100 hours of skill development keyboarding, were not significantly greater than preretraining Qwerty keyboard straight-copy rates for both CRT and element keyboarding equipment. The percentage of increase or decrease was not sizable for either CRT or element keyboarding equipment.

3. Dvorak keyboard production rates were found to be significantly different at 20- and 25-hour intervals for CRT and element keyboarding equipment, respectively, for 100 hours of skill-development keyboarding.

4. A significant difference was not found in Dvorak keyboard straight-copy rates between CRT and element keyboarding equipment treated independently. For this reason, the two groups were combined and their interval scores treated collectively. Dvorak keyboard straight-copy rates were found to be significantly different at ten-hour intervals for 100 hours of skill-development keyboarding on CRT/element equipment.

The combination of interval scores was possible in this analysis, since the same straight-copy timed writing performance measures were used for both CRT and element keyboarding equipment. For the production rates mentioned in

Conclusion 3 above, however, this treatment was not possible because different production measures were used by the equipment groups.

5. Significant interaction was not found between hours of keyboarding and keyboard equipment during 100 hours of Dvorak skill-development keyboarding.

6. Dvorak keyboard production rates were found to be linear for 100 hours of skill development keyboarding on CRT and element keyboarding equipment.

7. Dvorak keyboard straight-copy rate was found to be curvilinear for 100 hours of skill-development keyboarding on CRT/element keyboarding equipment.

These conclusions should be interpreted in light of the limitations and delimitations of this study found in Chapter 1.

Recommendations

1. Future studies should address the same production and straight-copy retraining performance measures used in this study to substantiate further the research findings.

2. Studies should be undertaken involving retraining of students in a classroom environment.

3. Studies should be undertaken to determine production performance unique to certain keyboarding tasks. For

example, performance indicators should be established for transcription and rough-draft production activities.

4. Research projects should be undertaken addressing reduction of operator fatigue and ease of keyboard operation resulting from retraining on the Dvorak keyboard.

5. A larger keyboard operator population should be used to substantiate further the results of Dvorak retraining as well as to allow for a more involved statistical analysis of the data.

6. Studies should be undertaken to compare the learning rates of beginning keyboard students on the Dvorak and Qwerty keyboards under experimental conditions.

7. Through the findings of this study, observation, and participant reaction, it is evident that the Dvorak keyboard is superior. Operators report ease of operation, less fatigue, reduced errors, and increased performance. Based on this evidence, it is recommended that:

a. Employers institute policies regarding employment of Dvorak keyboard operators.

b. Equipment manufacturers make the Dvorak keyboard part of their product line.

c. Educational institutions teach the Dvorak keyboard.

d. Qualified instructors be trained in Dvorak keyboard methodology for conducting initial training and retraining.

e. Publishers make Dvorak keyboard instructional materials available.

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